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Lab-scale Characterization of CO_2 Absorbents Containing Various Amine Species

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Abstract

Characterizations of CO_2 absorbents containing various amine species were carried out with their simple aqueous solutions and binary mixed solutions. Absorption and desorption process were demonstrated under the temperature of 50 °C and 80 °C, respectively. All absorbents were characterized using two indexes; absorption rate and release ratio. The results show typical primary amines have high absorption rate and low release ratio, while tertiary amines has low absorption rate and high release ratio. The characteristics of mixed absorbents changed continuously by changing compositions of mixed amine species. The result of quantitative analysis show negative relationship between bicarbonate formation and release ratio, indicating bicarbonate formation does not affect directly to release ratio of the CO_2 absorbent.

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Keywords: CO_2 capture; amine solvent; characterization

1. Introduction

Carbon Capture and Storage (CCS) technologies have received considerable attention because of the possible applications to prevent global warming by reducing greenhouse gas such as carbon dioxide (CO_2). Among CCS technologies, the chemical absorption process using amine species has most extensively been investigated for capturing CO_2 in exhaust gasses from power plants and other industrial

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facilities [1]. From the practical view point, however, the huge amounts of energy are needed in regeneration processes of chemical absorbents, and reduction of regeneration energy is called for commercial adaptation [2, 3]. So, we are developing chemical absorbents containing amine species and considering novel process to decrease regeneration energy. In this study, we report the result of characterization of CO_2 absorbents containing various amine species using screening test equipment.

2. Experimental

2.1. Reagents

Monoehtanolamine (MEA) and 2-amino-2-methyl-1-propanol (AMP), Diethanooamine (DEA), 2-methylaminoehtanol (MAE) , 2-ethylaminoehtanol (EAE) were purchased from Kanto Kagaku Co. (Tokyo, Japan). N-methyldiehanolamine (MDEA) and 2-isopropylaminoethanol (IPAE), Dimethylamino-2-propanol (DMA2P), Tris(hydroxymethyl)aminomethan (Tris), Piperazine (PZ) were purchased from Tokyo Kasei Co. (Tokyo, Japnan). All of the materials were of the highest grade available and were used as received.

2.2. Lab-scale equipment

Characterization of CO_2 absorbents was carried out using lab-scale equipment shown in Figure 1 considering two indexes; absorption rate and release ratio calculated as shown in Figure 2. CO_2 gas diluted with nitrogen (N_2) gas (CO_2 20% - N_2 80%) was fed into the CO_2 absorbent in the reactor of the screening test equipment through a ball filter (bubbler), then the concentration of CO_2 in the outlet gas of the reactor was continuously recorded using gas analyzer (VA-3001, HORIBA). CO_2 absorption process was demonstrated at the 50 °C in water bath, the reactor was put into another water bath at the 80 °C to evaluate regeneration process subsequently after 60 minutes of the absorption process. The amount of CO_2 absorbed was calculated from the change of CO_2 concentration in the outlet gas. Absorption rate were defined as the rate of absorption in the time of reaching 75% of the amount of absorption at 60 minutes, while release ratio defined as the ratio of the amount of absorption at 60 minute and the one at 90 minutes.

2.3. ^{13}C-NMR

For quantitative ^{13}C-NMR analysis, CO_2 loaded amine solutions containing D_2O were prepared at room temperature. ^{13}C-NMR spectra were measured at room temperature on a 500 MHz NMR spectrometer (JNM-ECX 500, JEOL). To obtain quantitative spectra, the inverse-gated decoupling method was used with a delay of 1 min and 128 scans.

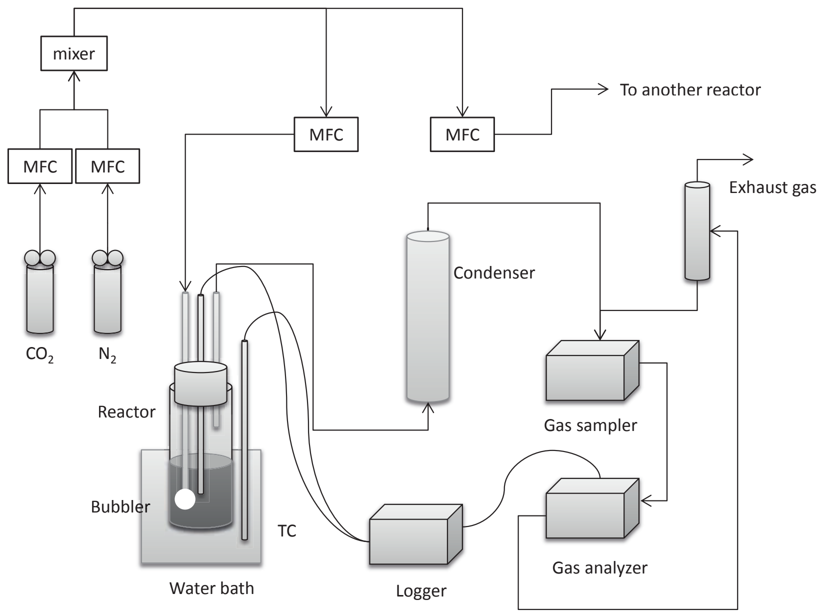

Fig. 1. A schematic illustration of lab-scale equipment.

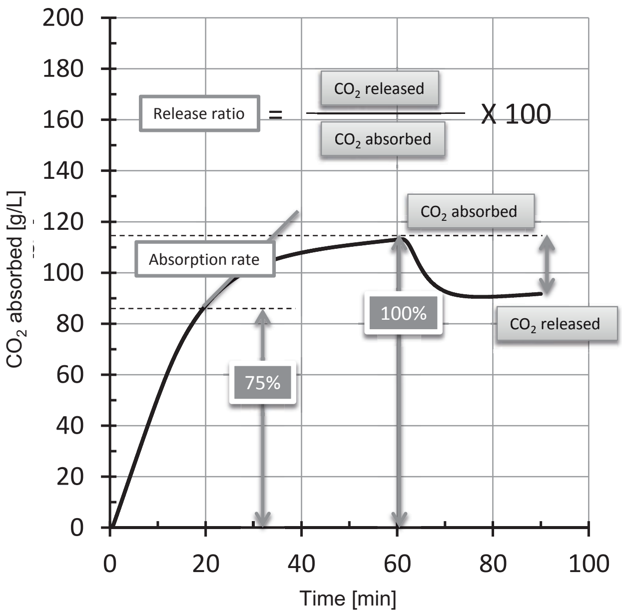

Fig. 2. The two indexes considered to evaluate CO_2 absorbents..

3. Result and Discussion

Prior to characterizations of various mixed amine solutions, typical alkanolamines and cyclicamines were evaluated with one’s simple substance aqueous solution to verify the validity of characterization using lab-scale equipment. Primary MEA has high absorption rate and low release ratio, while tertiary MDEA has low absorption rate and high release ratio. Furthermore, cyclic PZ shows high absorption rate even if the concentration of its simple aqueous solution is half of the one of alkanolamine because of two secondary amino groups are included in chemical structure.

Then, characterizations of the CO_2 absorbents containing various amine species mixed with PZ were carried out. The relationship between absorption rate and release ratio seems to have trade-off.

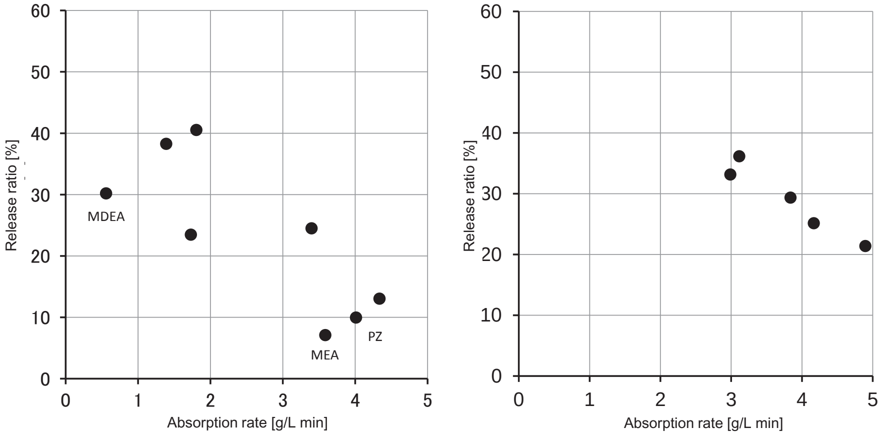

Fig. 3. Characterization of absorbents containing typical alkanol and cyclic amines with simple aqueous solutions (left) and binary mixed solutions containing PZ (right).

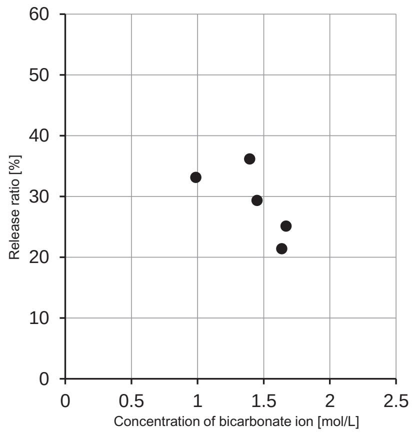

Fig. 4. Relationship between bicarbonate concentration and release ratio.

The characteristics of mixed absorbents changed continuously by changing compositions of mixed amine species. It would be expected that there are relevance between the chemical species and the characteristic of a mixed absorbent. For example, in case of the absorbent with high release performance, it has been reported that the main product of absorption process is bicarbonates.

In order to compare with these previous work, compositions of chemical species in CO_2 absorbents such as amines, protonated amines, carbamates, carbonates and bicarbonates were also evaluated with quantitative analysis using ^{13}C-NMR measurement. The relationship between bicarbonate concentration and release ratio are shown in Figure 4. These plots show negative relationship between bicarbonate formation and release ratio, indicating bicarbonate formation does not affect directly to release ratio of the CO_2 absorbent.

4. Conclusions

We have studied the characterizations of mixed CO_2 absorbents using lab-scale screening test equipment. The characteristics of CO_2 absorbents were clearly distinguished the absorbent with high absorption performance and the one with high regeneration performance. Relevance between the chemical species formed and the characteristic of a mixed absorbent were evaluated by ^{13}C-NMR quantitative analysis. The result of quantitative analysis show negative relationship between bicarbonate formation and release ratio.

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